

NCHRP

Project No. NCHRP 9-44 A

**Validating an Endurance Limit for HMA
Pavements:
Laboratory Experiment and Algorithm
Development**

Appendix 3

**Project Lab Test Results Inserted into the Mechanistic
Empirical Distress Prediction Models (M-E_DPM)
Database**

Prepared for

**NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
TRANSPORTATION RESEARCH BOARD
Of
The National Academies**

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INTRODUCTION

This appendix presents general information about the systematic recording of the major laboratory test data obtained from the lab experiments conducted in NCHRP Project 9-44A in a Microsoft Access® database named the Mechanistic-Empirical Distress Prediction Models (M-E_DPM) database, which was originally developed in NCHRP Project 9-30.

The major data groups that comprise the laboratory testing for NCHRP Project 9-44A are as follows:

1. HMA mix designs for three binder types: PG58-22, PG64-22, and PG76-16,
2. The weights of HMA loose mix loaded into the gyratory mold and the corresponding air voids of test specimens,
3. Binder test results including penetration-graded and performance-graded binder test results and Ai-VTSi relationships for the three binder types,
4. Dynamic modulus, phase angle, and E* master curve parameters,
5. Flexural beam fatigue results, and
6. Uniaxial tensile results including fingerprint tests.

The data recorded in the M-E_DPM database were developed by Arizona State University or AMEC Inc. (formerly MACTEC). Data input was accomplished by Arizona State University staff under the general guidance of a senior engineer from AMEC Inc.

The following sections provide detailed information on the items input for each of the major group noted above.

DATABASE DEVELOPMENT FOR NCHRP PROJECT 9-44A

The M-E_DPM database is coded in Microsoft Access® to provide a hierarchical database structure for storing pavement and materials information collected from major pavement sites (e.g., LTPP, WesTrack, MnRoad, NCAT, etc.). The database was developed to be mainly used for the future refinement, calibration, and validation of the HMA mechanic-empirical distress prediction models incorporated in the AASHTOWare Pavement ME Design program.

The objective of this database development in NCHRP Project 9-44A was to enhance this capability for future distress model calibration and validation, by adding the comprehensive laboratory experimental results obtained in the project.

Database Structure

The major tables in the program are shown on the left side of **Figure 1**. When it is opened (by a double click), the table illustrates specific information such as general, layer structure, material properties, distresses, units, etc. It is important to note that some tables are programmed to effectively connect with each other (i.e., any information displayed in a table can be found in other connected tables), and therefore, the user can use any of these tables for inputting or

retrieving data. Of those tables, the “CAL_Sections” table was designed to display the major project sites. Also, under this table, it was possible to add or create a new project section. The following three major categories were created under the table to input test results by binder performance grade:

- Arizona State Univ. (PG 58-28)
- Arizona State Univ. (PG 64-22)
- Arizona State Univ. (PG 76-16)

In the middle of **Figure 1**, a screenshot of the program shows the three category rows that were created.

The database is uniquely structured with multiple hierarchical levels. The user can expand or collapse the individual category section by clicking on a cell button beside each of the section ID cells. In **Figure 1**, each of the three Arizona State University categories can be expanded under each new sub-category or groups that were created.

It should be noted that this sub-group section was originally developed for inputting pavement layers from surface to subgrade. For each layer, another low level category can be created where the layer information is stored such as a thickness, volumetrics, etc. For the NCHRP Project 9-44A database development; the data to be placed into the database from the Arizona State University testing program were not from an actual pavement layer, but from laboratory experiments. As a result, several major laboratory test categories were created. The following lower level categories were created under each of the Arizona State University section IDs:

Section identification code (for LTPP section=state code+shrp id+construction no)

ID	Section_ID	Location	Section_Ler	Section_Ler	Latitude_D
281	8709021	0.25 km WEST OF THE PETAWAWA MILITARY CAMPTANK			
282	8709031	0.25 km WEST OF THE PETAWAWA MILITARY CAMPTANK			
317	Arizona State Univ. (PG 58-28)	ASU Tempe Campus, Arizona			
316	Arizona State Univ. (PG 64-22)	ASU Tempe Campus, Arizona			
318	Arizona State Univ. (PG 76-16)	ASU Tempe Campus, Arizona			
292	CAL/APT 500RF	1 Richmond Field Station, University of California at Berkeley (UC)			
293	CAL/APT 501RF	1 Richmond Field Station, University of California at Berkeley (UC)			
294	CAL/APT 502CT	1 Richmond Field Station, University of California at Berkeley (UC)			
295	CAL/APT 503RF	1 Richmond Field Station, University of California at Berkeley (UC)			
296	CAL/APT 504RF	1 Richmond Field Station, University of California at Berkeley (UC)			
297	CAL/APT 505RF	1 Richmond Field Station, University of California at Berkeley (UC)			
298	CAL/APT 506RF	1 Richmond Field Station, University of California at Berkeley (UC)			
299	CAL/APT 507RF	1 Richmond Field Station, University of California at Berkeley (UC)			
300	CAL/APT 508RF	1 Richmond Field Station, University of California at Berkeley (UC)			
301	CAL/APT 509RF	1 Richmond Field Station, University of California at Berkeley (UC)			
302	CAL/APT 510RF	1 Richmond Field Station, University of California at Berkeley (UC)			
303	CAL/APT 511RF	1 Richmond Field Station, University of California at Berkeley (UC)			
304	CAL/APT 512RF	1 Richmond Field Station, University of California at Berkeley (UC)			
305	CAL/APT 513RF	1 Richmond Field Station, University of California at Berkeley (UC)			
306	CAL/APT 514RF	1 Richmond Field Station, University of California at Berkeley (UC)			
307	CAL/APT 515RF	1 Richmond Field Station, University of California at Berkeley (UC)			
309	CAL/APT 517RF	1 Richmond Field Station, University of California at Berkeley (UC)			
310	CAL/APT 518RF	1 Richmond Field Station, University of California at Berkeley (UC)			
311	CAL/APT 543RF	1 Richmond Field Station, University of California at Berkeley (UC)			
312	CAL/APT 544RF	1 Richmond Field Station, University of California at Berkeley (UC)			
36	FHWA_ALF_Ln10_S1	1 Tested by FHWA Accelerated Loading Facility (ALF) on Lane 1			
37	FHWA_ALF_Ln10_S2	1 Tested by FHWA Accelerated Loading Facility (ALF) on Lane 1			
38	FHWA_ALF_Ln11_S1	1 Tested by FHWA Accelerated Loading Facility (ALF) on Lane 1			
39	FHWA_ALF_Ln11_S2	1 Tested by FHWA Accelerated Loading Facility (ALF) on Lane 1			
40	FHWA_ALF_Ln12_S1	1 Tested by FHWA Accelerated Loading Facility (ALF) on Lane 1			

Figure 1 Screenshot of the Database: ASU Section IDs under the “CAL_Sections” Table

ASU Section ID: Arizona State Univ. (PG 58-28)

- HMA (Mix Design)
 - HMA (Binder Testing, PAV)
 - HMA (Binder Testing, RTFO)
 - HMA (Binder Testing, PAV)
 - HMA (E*, PG58-28, AC 4.2%, VA 9.5%)
 - HMA (E*, PG58-28, AC 4.2%, VA 7.0%)
 - HMA (E*, PG58-28, AC 4.2%, VA 4.5%)
 - HMA (E*, PG58-28, AC 4.7%, VA 9.5%)
 - HMA (E*, PG58-28, AC 4.7%, VA 7.0%)
 - HMA (E*, PG58-28, AC 4.7%, VA 4.5%)
 - HMA (E*, PG58-28, AC 5.2%, VA 9.5%)
 - HMA (E*, PG58-28, AC 5.2%, VA 7.0%)
 - HMA (E*, PG58-28, AC 5.2%, VA 4.5%)
 - HMA (Beam Fatigue, PG 58-28, AC 4.2%, VA 4.5%)
 - HMA (Beam Fatigue, PG 58-28, AC 4.2%, VA 9.5%)
 - HMA (Beam Fatigue, PG 58-28, AC 5.2%, VA 4.5%)
 - HMA (Beam Fatigue, PG 58-28, AC 5.2%, VA 9.5%)
- ASU Section ID: Arizona State Univ. (PG 64-22)
- *The same items as the PG 58-28 category (from Mix Design to Beam Fatigue)*
 - HMA (Fingerprint Test, PG 64-22, AC 4.2%, VA 4.5%)
 - HMA (Fingerprint Test, PG 64-22, AC 5.2%, VA 4.5%)
 - HMA (Fingerprint Test, PG 64-22, AC 4.2%, VA 9.5%)
 - HMA (Fingerprint Test, PG 64-22, AC 5.2%, VA 9.5%)
 - HMA (Uniaxial Fatigue, PG 64-22, AC 4.2%, VA 4.5%)
 - HMA (Uniaxial Fatigue, PG 64-22, AC 5.2%, VA 4.5%)
 - HMA (Uniaxial Fatigue, PG 64-22, AC 4.2%, VA 9.5%)
 - HMA (Uniaxial Fatigue, PG 64-22, AC 5.2%, VA 9.5%)
- ASU Section ID: Arizona State Univ. (PG 76-16)
- *The same items as the PG 58-28 category (from Mix Design to Beam Fatigue)*

There are five major data groups under the PG 58-28 and PG 76-16 binders: mix design, binder testing, E*, beam fatigue, and the relationship between specimen air voids and mass of loose HMA mix. For the PG 64-22 binder, in particular, in addition to these five groups, there are two additional groups: finger print and uniaxial fatigue. These two categories are the major outputs from the uniaxial testing. It should be recognized that under each of the major test result group (i.e., mix design, binder testing, E*, beam fatigue, air voids–mass, fingerprint, and uniaxial fatigue), lower level groups are subsequently placed and each of the lower level group contains detailed test results. This information is explained in the following sections. Figure 2 shows a screenshot of the database containing the major data groups.

CAL_Sections - Microsoft Access

Table Tools

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Tables

- CAL_CLM_Summary
- CAL_Layers
- CAL_Lookup
- CAL_Lookup_Units
- CAL_MON_Alligator Crack...
- CAL_MON_IRI
- CAL_MON_Longitudinal C...
- CAL_MON_Rutting
- CAL_MON_Transverse Crac...
- CAL_Property_Dictionary
- CAL_Property_Values
- CAL_Qualifier_Values
- CAL_Sections**
- CAL_TRF_Summary
- CLM_OWS_LOCATION
- CLM_SITE_VWS_LINK
- CLM_VWS_HUMIDITY_ANN...
- CLM_VWS_HUMIDITY_MO...
- CLM_VWS_OWS_LINK
- CLM_VWS_PRECIP_ANNUAL
- CLM_VWS_PRECIP_MONTH
- CLM_VWS_TEMP_ANNUAL
- CLM_VWS_TEMP_MONTH
- CLM_VWS_WIND_ANNUAL

ID	Section_ID	Location	Section_Ler	Section_Ler	Latitude_De
281	8709021	0.25 km WEST OF THE PETAWAWA MILITARY CAMPTANK			
282	8709031	0.25 km WEST OF THE PETAWAWA MILITARY CAMPTANK			
317	Arizona State Univ. (PG 58-28)	ASU Tempe Campus, Arizona			
316	Arizona State Univ. (PG 64-22)	ASU Tempe Campus, Arizona			

ID	Layr	Description	Thic	Thicki	Lookup to Material	Comments
1518		HMA (E*, PG 64-22, AC 4.0%, VA 10.0%)				
1519		HMA (Binder Testing, Neat)				
1520		HMA (Binder Testing, RTFO)				
1521		HMA (Binder Testing, PAV)				
1522		HMA (Mix Design)				19mm Maricopa County Spec, I
1523		HMA (E*, PG 64-22, AC 4.0%, VA 7.0%)				
1524		HMA (E*, PG 64-22, AC 4.0%, VA 4.0%)				
1525		HMA (E*, PG 64-22, AC 4.5%, VA 10.0%)				
1526		HMA (E*, PG 64-22, AC 4.5%, VA 7.0%)				
1527		HMA (E*, PG 64-22, AC 4.5%, VA 4.0%)				
1528		HMA (E*, PG 64-22, AC 5.0%, VA 10.0%)				
1529		HMA (E*, PG 64-22, AC 5.0%, VA 7.0%)				
1530		HMA (E*, PG 64-22, AC 5.0%, VA 4.0%)				
1573		HMA (Beam Fatigue, PG 64-22, AC 4.2%, VA 4.5%)				
1574		HMA (Beam Fatigue, PG 64-22, AC 4.2%, VA 4.5%)				
1575		HMA (Beam Fatigue, PG 64-22, AC 5.2%, VA 4.5%)				
1576		HMA (Beam Fatigue, PG 64-22, AC 5.2%, VA 9.5%)				
1581		HMA (Finger Print Test, PG 64-22, AC 4.2%, VA 4.5%)				
1582		HMA (Finger Print Test, PG 64-22, AC 5.2%, VA 4.5%)				
1583		HMA (Finger Print Test, PG 64-22, AC 4.2%, VA 9.5%)				
1584		HMA (Finger Print Test, PG 64-22, AC 5.2%, VA 9.5%)				
1585		HMA (Uniaxial Fatigue, PG 64-22, AC 4.2%, VA 4.5%)				
1586		HMA (Uniaxial Fatigue, PG 64-22, AC 5.2%, VA 4.5%)				
1587		HMA (Uniaxial Fatigue, PG 64-22, AC 4.2%, VA 9.5%)				
1588		HMA (Uniaxial Fatigue, PG 64-22, AC 5.2%, VA 9.5%)				

Record: 197 of 294

Section identification code (for LTPP section=state code+shrp id+construction no)

Figure 2 Screenshot of the Database: Hierarchical Structure

Mix Design Data Input

The mix designs of each of the asphalt binder types (three PG binder types) used for the project were summarized from MACTEC reports completed in the early stages of the project. Key properties of the mix design were input and stored in the database. The following properties, in alphabetical order, are displayed in the database; a screenshot of the database program showing these properties is presented in **Figure 3**:

- Air Voids (Design)
- Asphalt Absorption into Dry Aggregate
- Asphalt Content by Weight
- Binder Grade (PG)
- Bulk Specific Gravity (Combined Aggregate)
- Bulk Specific Gravity of Coarse Aggregate
- Bulk Specific Gravity of Fine Aggregate
- Bulk Specific Gravity of HMA Mix
- Compaction Temperature
- Dust to Effective Asphalt Ratio
- Film Thickness
- Flat and Elongate of Aggregate
- Fractured Face One
- Fractured Face Two
- LA Abrasion at 500 Rev
- Max Specific Gravity of HMA Mix
- Mixing Temperature
- Passing 0.075mm
- Passing 0.15mm
- Passing 0.30mm
- Passing 0.475mm
- Passing 0.60mm
- Passing 1.18mm
- Passing 12.5mm
- Passing 19.0mm
- Passing 2.0mm
- Passing 2.36mm
- Passing 25.0mm
- Passing 31.3mm
- Passing 37.5mm
- Passing 4.75mm
- Passing 6.3mm

- Passing 9.5mm
- Sand Equivalent
- Specific Gravity of HMA Binder
- Tensile Strength Ratio
- Uncompacted Voids
- Voids Filled with Asphalt (VFA)
- Voids in Mineral Aggregate (VMA)
- Water Absorption of Combined Aggregates

Asphalt Binder Test Results

The asphalt binder test results were input into the database. These data include the penetration-graded (penetration and softening point) and performance-graded binder (Brookfield Viscosity) test results for the three PG binder types. For each binder type, test results were obtained under three specific aging conditions: original or neat condition, short-term aged condition (RTFO), and long-term aged condition (PAV). The binder data also include the test temperature and calculated viscosity. The temperature is recorded in three different units: degrees Fahrenheit, degrees Celsius, and degrees Rankine (used in computing the binder A_i - VTS_i value). The viscosity values are expressed in centipoises.

The regression parameters (A_i and VTS_i) computed from the temperature-viscosity relationship for each binder type were also entered into the database, using the temperature in degrees Rankine and viscosity in centipoise.

The following list shows the input items of the database; a database screenshot showing these items is presented in **Figure 4**. Since all binder testing was conducted in replicate over a wide range of test conditions, multiple rows were created with the same property name where the test condition and resulting values are unique for each row of the database.

- A_i (Intercept of the viscosity – temperature relationship)
- VTS_i (Slope of the viscosity – temperature relationship)
- Binder Grade (PG)
- Penetration
 - o Age (Neat or RTFO or PAV)
 - o Temperature in deg. Celsius
 - o Temperature in deg. Fahrenheit
 - o Temperature in deg. Rankine
 - o Temperature in deg. Rankine (Log value)
 - o Viscosity in Centipoise
 - o Viscosity in Centipoise (Log Log value)

Table Tools
CAL_Sections - Microsoft Access

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Tables

ID	Section_ID	LTTP_Section	STATE_CODE	SHRP_ID	CONSTRUCTION_NO	Location	Section
280	8709011	<input checked="" type="checkbox"/>	87	0901	1	0.25 km WEST OF THE PETAWAWA MILITARY CAMPTANK CROSSING	
281	8709021	<input checked="" type="checkbox"/>	87	0902	1	0.25 km WEST OF THE PETAWAWA MILITARY CAMPTANK CROSSING	
282	8709031	<input checked="" type="checkbox"/>	87	0903	1	0.25 km WEST OF THE PETAWAWA MILITARY CAMPTANK CROSSING	
317	Arizona State Univ. (PG 58-28)	<input type="checkbox"/>				ASU Tempe Campus, Arizona	

1539 HMA (Mix Design) 19mm Maricopa County Spec, High

ID	Layer	Description	Thick	Thickr	Lookup to Material	Comments
15138		Air_Voids	3.9			percent
15102		Asphalt Absorption into Dry Aggregate	0.5			percent
15103		Asphalt Content by weight	4.8		Measured (Lab)	percent
15104		Binder_Grade	PG58-28			
15105		Bulk Specific Gravity (Combined)	2.614			
15106		Bulk_Specific_Gravity_HMA_Coarse_Aggreg	2.615			
15107		Bulk_Specific_Gravity_HMA_Fine_Aggregat	2.612			
15108		Bulk_Specific_Gravity_HMA_Mix	2.365		Measured (Lab)	percent
15109		Compaction Temperature	280			degrees Fahrenh
15137		Dust to Effective Asphalt Ratio	0.76			
15136		Film Thickness	11.2			microns
15110		Flat and Elongate of Aggregate	1.0			percent
15111		Fractured Face One (%)	99			percent
15112		Fractured Face Two (%)	96			percent
15113		LA Abrasion at 500 Rev	16			percent
15114		Max_Specific_Gravity_HMA_Mix	2.461		Measured (Lab)	
15115		Mixing Temperature	300			degrees Fahrenh
15116		Passing_0_075mm	3.3		Measured (Lab)	
15117		Passing_0_15mm	5		Measured (Lab)	
15118		Passing_0_30mm	10		Measured (Lab)	
15119		Passing_0_425mm	13		Measured (Lab)	
15120		Passing_0_60mm	17		Measured (Lab)	
15121		Passing_1_18mm	23		Measured (Lab)	
15122		Passing_12_5mm	80		Measured (Lab)	
15123		Passing_19mm	95		Measured (Lab)	
15141		Passing_2_0mm	28		Measured (Lab)	

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Section ID Num Lock

Figure 3 Screenshot of the Database: Mix Design Data Input

Table Tools
CAL_Sections - Microsoft Access

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Toggle Filter

Window
Size to Fit Form Switch Windows

Find
Replace Go To Select

Tables

CAL_MON_Alligator Cracki...
CAL_MON_IRI
CAL_MON_Longitudinal Cr...
CAL_MON_Rutting
CAL_MON_Transverse Crac...
CAL_Property_Dictionary
CAL_Property_Values
CAL_Qualifier_Values
CAL_Sections
CAL_TRF_Summary
CLM_OWS_LOCATION
CLM_SITE_VWS_LINK
CLM_VWS_HUMIDITY_ANN...
CLM_VWS_HUMIDITY_MO...
CLM_VWS_OWS_LINK
CLM_VWS_PRECIP_ANNUAL
CLM_VWS_PRECIP_MONTH
CLM_VWS_TEMP_ANNUAL
CLM_VWS_TEMP_MONTH
CLM_VWS_WIND_ANNUAL
CLM_VWS_WIND_MONTH
INSITU_MOISTURE_DENSITY
MON_DEFL_BUFFER_SHAPE
MON_DEFL_DEV_CONFIG
MON_DEFL_DEV_SENSORS
MON_DEFL_DROP_DATA
MON_DEFL_EST_SENSOR_...
MON_DEFL_FLX_BAKCAL_B...

ID	Section_ID	LTPP_Section	STATE_CODE	SHRP_ID	CONSTRUCTION_NO	Location	Section
280	8709011	<input checked="" type="checkbox"/>	87	0901	1	0.25 km WEST OF THE PETAWAWA MILITARY CAMPTANK CROSSING	
281	8709021	<input checked="" type="checkbox"/>	87	0902	1	0.25 km WEST OF THE PETAWAWA MILITARY CAMPTANK CROSSING	
282	8709031	<input checked="" type="checkbox"/>	87	0903	1	0.25 km WEST OF THE PETAWAWA MILITARY CAMPTANK CROSSING	
317	Arizona State Univ. (PG 58-28)	<input type="checkbox"/>				ASU Tempe Campus, Arizona	

ID	Layer	Description	Thicl	Thickr	Lookup to Material	Comments
1539		HMA (Mix Design)				19mm Maricopa County Spec, High
1540		HMA (Binder Testing, PAV)				PG58-28
1541		HMA (Binder Testing, RTFO)				PG58-28
1542		HMA (Binder Testing, Neat)				PG58-28

ID	Lookup to Property Name	Value	Lookup to Property V	Lookup to Value Method	Lookup to Unit	Date	Cr
15148	A Intercept	10.8041		Estimated			
15149	Binder_Grade	PG 58-28					
15157	Penetration	5.0		Measured (Lab)	0.1 millimeters		
15167	Penetration	5.00		Measured (Lab)	0.1 millimeters		
15166	Penetration	11.80		Measured (Lab)	0.1 millimeters		
15165	Penetration	14.80		Measured (Lab)	0.1 millimeters		
15164	Penetration	59.20		Measured (Lab)	0.1 millimeters		
15163	Penetration	62.00		Measured (Lab)	0.1 millimeters		

ID	Lookup to Property Qualifier	Qualifier_Value	Qualifier_Value Te	Lookup to Qualifier_Value_Metho	Lookup to Qualifier_Test_Protoc	Looku
25355	Age	Neat				
25356	Temperature	23.1		Computed		degree
25357	Temperature	73.6		Measured (Lab)		degree
25358	Temperature	533.3		Computed		degree
25359	Temperature	2.727		Computed		degree
25360	Viscosity	2.90E+08		Measured (Lab)		centipi
25361	Viscosity	0.928		Computed		centipi
*	(New)					
15162	Penetration	108.75		Measured (Lab)	0.1 millimeters	
15161	Penetration	115.25		Measured (Lab)	0.1 millimeters	
15160	Penetration	5.20		Measured (Lab)	0.1 millimeters	
15158	Penetration	14.20		Measured (Lab)	0.1 millimeters	
15169	Penetration	45.80		Measured (Lab)	0.1 millimeters	
15156	Penetration	147.50		Measured (Lab)	0.1 millimeters	

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No Filter Search

Section ID Num Lock

Figure 4 Screenshot of the Database: Binder Test Results Input

- Softening Point
 - o Age (Neat or RTFO or PAV)
 - o Viscosity in Centipoise (Log Log value)
- Brookfield
 - o Age (Neat or RTFO or PAV)
 - o Viscosity in Centipoise (Log Log value)

Dynamic Modulus Test Results

The dynamic modulus (E^*) test results obtained at Arizona State University were also incorporated into the database. Similar to the other tests, E^* tests were performed with the specimens manufactured with the three performance-graded binders. Therefore, under each of the main ASU section IDs shown in the previous section; the detailed test results were inputted. The properties included in the database are as follows; a screenshot showing the inputs is presented in **Figure 5**:

- Dynamic Modulus (E^* values at each test temperature – frequency combinations)
 - o Temperature in deg. Fahrenheit
 - o Frequency in Hz
 - o Standard Deviation
 - o Coefficient of Variation
- Phase Angle (phase angle at each test temperature-frequency combinations)
 - o Temperature in deg. Fahrenheit
 - o Frequency in Hz
 - o Standard Deviation
 - o Coefficient of Variation
- E^* Master Curve parameters
 - o Alpha
 - o Beta
 - o Gamma
 - o Delta
 - o a (time-temperature shift function coefficient for the regression model)
 - o b (time-temperature shift function coefficient for the regression model)
 - o c (time-temperature shift function coefficient for the regression model)

Beam Fatigue Test Results

Over 450 test specimens were manufactured and tested for the flexible beam fatigue behavior study at Arizona State University. The experimental test conditions included three levels of

Table Tools

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Calibri 11 Font Rich Text

Refresh All New Save Totals Spelling Filter Selection Advanced Size to Fit Form Switch Windows Find Replace Go To Select Find

Tables

CAL_MON_Alligator Cracki...
CAL_MON_IRI
CAL_MON_Longitudinal Cr...
CAL_MON_Rutting
CAL_MON_Transverse Crac...
CAL_Property_Dictionary
CAL_Property_Values
CAL_Qualifier_Values
CAL_Sections
CAL_TRF_Summary
CLM_OWS_LOCATION
CLM_SITE_VWS_LINK
CLM_VWS_HUMIDITY_ANN...
CLM_VWS_HUMIDITY_MO...
CLM_VWS_OWS_LINK
CLM_VWS_PRECIP_ANNUAL
CLM_VWS_PRECIP_MONTH
CLM_VWS_TEMP_ANNUAL
CLM_VWS_TEMP_MONTH
CLM_VWS_WIND_ANNUAL
CLM_VWS_WIND_MONTH
INSITU_MOISTURE_DENSITY
MON_DEFL_BUFFER_SHAPE
MON_DEFL_DEV_CONFIG
MON_DEFL_DEV_SENSORS
MON_DEFL_DROP_DATA
MON_DEFL_EST_SENSOR_...
MON_DEFL_FLX_BAKCAL_B...

ID	Section_ID	LTTP_Section	STATE_CODE	SHRP_ID	CONSTRUCTION_NO	Location	Section
280	8709011	<input checked="" type="checkbox"/>	87	0901	1	0.25 km WEST OF THE PETAWAWA MILITARY CAMPTANK CROSSING	
281	8709021	<input checked="" type="checkbox"/>	87	0902	1	0.25 km WEST OF THE PETAWAWA MILITARY CAMPTANK CROSSING	
282	8709031	<input checked="" type="checkbox"/>	87	0903	1	0.25 km WEST OF THE PETAWAWA MILITARY CAMPTANK CROSSING	
317	Arizona State Univ. (PG 58-28)	<input type="checkbox"/>				ASU Tempe Campus, Arizona	

ID	Layer	Description	Thicl	Thickr	Lookup to Material	Comments
1539		HMA (Mix Design)				19mm Maricopa County Spec, High
1540		HMA (Binder Testing, PAV)				PG58-28
1541		HMA (Binder Testing, RTFO)				PG58-28
1542		HMA (Binder Testing, Neat)				PG58-28
1543		HMA (E*, PG 58-28, AC 4.2%, VA 9.5%)				

ID	Lookup to Property Name	Value	Lookup to Property V	Lookup to Value Method	Lookup to Unit	Date	Cr
15297	Modulus_Dynamic_E*	811					Repl. 1 (745 ks
15327	Modulus_Dynamic_E*	101					Repl. 1 (107 ks
15290	Modulus_Dynamic_E*	263					Repl. 1 (283 ks
15291	Modulus_Dynamic_E*	238					Repl. 1 (232 ks
15292	Modulus_Dynamic_E*	364					Repl. 1 (351 ks
15293	Modulus_Dynamic_E*	432					Repl. 1 (413 ks
15294	Modulus_Dynamic_E*	633					Repl. 1 (604 ks
15296	Modulus_Dynamic_E*	884					Repl. 1 (798 ks
15285	Modulus_Dynamic_E*	2527					Repl. 1 (2832 k
15298	Modulus_Dynamic_E*	2642					Repl. 1 (3024 k
15299	Modulus_Dynamic_E*	1184					Repl. 1 (1129 k

ID	Lookup to Property Qualifier	Qualifier_Value	Qualifier_Value Te	Lookup to Qualifier_Value_Metho	Lookup to Qualifier_Test_Protoc	Lookup
20378	Temperature	40				degree
20379	Frequency	1				hertz
20380	Standard Deviation	78				kips/sc
20381	CV	6.5				percen
*	(New)					
15300	Modulus_Dynamic_E*	191				Repl. 1 (205 ks
15301	Modulus_Dynamic_E*	1602				Repl. 1 (1601 k
15302	Modulus_Dynamic_E*	1732				Repl. 1 (1801 k
15303	Modulus_Dynamic_E*	1807				Repl. 1 (1972 k
15325	Modulus_Dynamic_E*	57				Repl. 1 (56 ksi)

Record: 11 of 60 No Filter Search

Section ID Num Lock

Figure 5 Screenshot of the Database: E* Test Results Input

temperature (40, 70 and 100°F), three levels of binder type (PG 58-22, PG 64-22, and PG 76-16), two levels of asphalt content (4.2 and 5.2%), and two levels of air voids (4.5 and 9.5%). With these variable levels, the following four major categories were established for each binder type for systematic input of the test data:

- HMA (Beam Fatigue, AC 4.2%, VA 4.5%)
- HMA (Beam Fatigue, AC 4.2%, VA 9.5%)
- HMA (Beam Fatigue, AC 5.2%, VA 4.5%)
- HMA (Beam Fatigue, AC 5.2%, VA 9.5%)

In each of these major categories, the two major beam fatigue test were recorded: Number of Cycles to Beam Fatigue and Stiffness Ratio. Each of these properties is characterized by several test parameters, which are also recorded in the database, as follows:

- Number of Cycles to Beam Fatigue
 - o Strain
 - o Stress
 - o Initial Stiffness
 - o Rest Period
 - o Test Temperature
- Stiffness Ratio
 - o Strain
 - o Stress
 - o Initial Stiffness
 - o Rest Period
 - o Test Temperature
 - o Number of Cycles

Further, there are numerous test replicates with the same asphalt content and air voids. As a result, under the same air voids – asphalt content category, several replicate properties are found as shown in **Figure 6**. Note that the specimen (replicate) IDs are displayed at the end of each row.

Uniaxial Test Results

The last major laboratory test conducted by Arizona State University was the uniaxial test. This category of testing was only completed for the PG-64 binder mixtures. Two major test categories were obtained for the test: fingerprint and uniaxial fatigue. These data were organized in the same 2x2 matrix as that established for the beam fatigue test with two levels of air voids (4.5 and 9.5%) and two levels of asphalt contents (4.2 and 5.2%):

- HMA (Fingerprint Test, AC 4.2%, VA 4.5%)
- HMA (Fingerprint Test, AC 4.2%, VA 9.5%)

- HMA (Fingerprint Test, AC 5.2%, VA 4.5%)
- HMA (Fingerprint Test, AC 5.2%, VA 9.5%)
- HMA (Uniaxial Fatigue, AC 4.2%, VA 4.5%)
- HMA (Uniaxial Fatigue, AC 4.2%, VA 9.5%)
- HMA (Uniaxial Fatigue, AC 5.2%, VA 4.5%)
- HMA (Uniaxial Fatigue, AC 5.2%, VA 9.5%)

Three major properties were recorded for the fingerprint test: Machine Compliance Factor, Fingerprint Modulus, and Phase Angle. Two major properties were recorded for the uniaxial fatigue test: Number of Cycles to Failure and Pseudo Stiffness Ratio. The related test conditions were also recorded in the database for each property. These are summarized as follows; a screenshot is presented in **Figure 7**:

- Machine Compliance Factor
 - o Actual Air Voids measured for Test Specimen
 - o Temperature
 - o Strain
 - o Rest Period
- Fingerprint Modulus
 - o Actual Air Voids measured for Test Specimen
 - o Temperature
 - o Strain
 - o Rest Period
- Phase Angle
 - o Actual Air Voids measured for Test Specimen
 - o Temperature
 - o Strain
 - o Rest Period
- Number of Cycles to Failure
 - o Actual Air Voids measured for Test Specimen
 - o Temperature
 - o Strain
 - o Rest Period
 - o Initial Stiffness
 - o Initial Tensile Stress
- Number of Cycles

CAL_Sections - Microsoft Access

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ID	Section_ID	Location	Section_Ler	Section_Ler	Latitude_Degre	Latitude_Minute	La
280	8709011	0.25 km WEST OF THE PETAWAWA MILITARY CAMPTANK			45	57	
281	8709021	0.25 km WEST OF THE PETAWAWA MILITARY CAMPTANK			45	57	
282	8709031	0.25 km WEST OF THE PETAWAWA MILITARY CAMPTANK			45	57	
317	Arizona State Univ. (PG 58-28)	ASU Tempe Campus, Arizona					
316	Arizona State Univ. (PG 64-22)	ASU Tempe Campus, Arizona					

ID	Layer	Description	Thic	Thicki	Lookup to Material	Comments
1576		HMA (Beam Fatigue, PG 64-22, AC 5.2%, VA 9.5%)				
1581		HMA (Finger Print Test, PG 64-22, AC 4.2%, VA 4.5%)				

ID	Lookup to Property Name	Value	Lookup to Property 1	Lookup to Value Method	Lookup to Uni	Date	Comme
18324	Air_Voids	4.5			percent		Specimen ID: D-41
18323	Asphalt Content by weight	4.2			percent		Specimen ID: D-41
18325	Binder_Grade	PG 64-22					
18344	Machine Compliance Factor						Specimen ID: D-40
18341	Machine Compliance Factor	12.00					Specimen ID: D-44
18328	Machine Compliance Factor	11.89					Specimen ID: D-41

ID	Lookup to Property Qualifie	Qualifier_Value	Qualifier_Value Te	Lookup to Qualifier_Value_Methc	Lookup to Qualifier_Test_Protor	Lookup to Q
39395	Temperature	40				degrees Fahrenheit
39396	Actual Va (Lab Specimen)	4.84				percent
39397	Strain	95				microstrains
39398	Rest Period	0				seconds
*	(New)					

ID	Modulus_Finger_Print	Value	Unit	Specimen ID
18345	Modulus_Finger_Print		kips/square inch	Specimen ID: D-40
18342	Modulus_Finger_Print	2624.7	kips/square inch	Specimen ID: D-44
18326	Modulus_Finger_Print	2573.7	kips/square inch	Specimen ID: D-41
18346	Phase_Angle_Delta		degrees	Specimen ID: D-40
18343	Phase_Angle_Delta	11.51	degrees	Specimen ID: D-44
18327	Phase_Angle_Delta	9.32	degrees	Specimen ID: D-41
*	(New)			

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Figure 7 Screenshot of the Database: Uniaxial Results Input

- Pseudo Stiffness Ratio
 - o Actual Air Voids measured for Test Specimen
 - o Temperature
 - o Strain
 - o Rest Period
 - o Initial Stiffness
 - o Initial Tensile Stress
 - o Number of Cycles

Specimen Air Voids and Mass of Molded Loose HMA Mix Data

The test specimens used for E^* testing conducted at Arizona State University were prepared based on the relationships between mass and air voids. The mass in this context is defined as an amount (weight) of loose asphalt mix placed into the Superpave gyratory mold; the air voids represent the actual air voids calculated from the G_{mm} and G_{mb} values of the test specimens. For each binder type, three different levels of HMA mass were used. The same weights were applied to each binder content level and the corresponding air voids of each specimen were measured. Therefore, the matrix of three levels of the asphalt contents and three actual air void levels for each binder content level were created in the database.

Figure 8 shows a screenshot of the M-E_DPM database program for PG 58-28. There are nine categories (three binder content levels by three actual air voids level). Under each category, the following mix information was recorded:

- Actual Air Voids measured for Test Specimen
- Loose Mix Weight into the Gyratory Mold
- Asphalt Content by Weight
- Bulk Specific Gravity of HMA Mix (G_{mb})
- Theoretical Maximum Specific Gravity of HMA Mix (G_{mm})

Summary

The M-E_DPM database program, originally developed under NCHRP Project 9-30, has been expanded by adding the laboratory test results obtained from NCHRP Project 9-44A conducted at Arizona State University. The purpose of the program was to provide a hierarchical database structure for storing pavement and materials information collected from major pavement sites. The database was developed to be mainly used for the future refinement, calibration, and validation of the HMA mechanic-empirical distress prediction models incorporated in the AASHTOWare Pavement ME Design program.

The objective of this database's development under NCHRP 9-44A was to enhance the current version of the M-E_DPM database program and maximize the capability for its potential use in

the distress model calibration and validation. This was accomplished by adding the comprehensive laboratory experiment results extensively conducted at Arizona State University during NCHRP Project 9-44A. The major tests conducted by Arizona State University were:

- HMA Mix Designs for three binder types: PG58-22, PG64-22, and PG76-16
- Binder test results including conventional and Superpave binder test results and Ai-VTSi relationships for the three binder types
- Dynamic modulus, phase angle, and E^* Master Curve parameters
- Flexural beam fatigue results
- Uniaxial tensile results including fingerprint test
- Air voids and mass of loose HMA mix into mold

